Dynamics of ultra-cold indirect excitons in a trap

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The realization of microscopic traps for ultra-cold exciton gases constitutes a key step for fundamental studies, notably to explore collective quantum phenomena, but also for applied research as it allows for the development of exciton based opto-electronics devices. In recent years, important progress has been made with the so-called spatially indirect excitons confined in double quantum wells (DQW). Techniques to capture indirect excitons have been developed, e.g. stress or magnetically induced traps. In addition, a series of experiments has shown that the quantum confined Stark effect, i.e. the interaction between the well oriented electric dipole of indirect excitons and an external electric field, provides a direct access to exciton trapping. Indeed, indirect excitons are high-field seekers and then captured by electric field gradients imprinted in the plane of a DQW. Hence, devices employing micro-patterned gate electrodes have lead to an unprecedented degree of control over the transport of indirect excitons, however at the cost of highly-demanding lithographic processes.

Here, we introduce an alternative to the state-of-the-art technology in order to control the confinement of spatially indirect excitons. Precisely, we show that the optically controlled injection and spatial patterning of charges trapped in a field-effect device can create dynamically and on-demand potential landscapes where ultra-cold and dense gases are captured. Trapped charges locally modify the internal electric field and create optically defined potential gradients. Thus, arbitrary confinement geometries are directly created simply by shaping the spatial profile of a laser excitation. We then realized hollow and ring traps for indirect excitons, i.e. traps with circular and ring-shaped potential barriers respectively, but also artificial one-dimensional lattices.

Optically injected charges yield trapping potentials with depths in the range of several meV. The resulting traps do not vary over time such that laser sequences may be utilized to first imprint a confining potential where indirect excitons are subsequently injected optically. In the high-density regime, the relaxation dynamics reveals that confined gases are well thermalized. For our experiments realized at 350 mK quantum statistical effects are then theoretically predicted, consequently we discuss the quantum coherence of trapped exciton gases.